ISSN: 1996–2452 RNPS: 2148
Revista PODIUM, January-April 2020; 15(1): 111-126

PODIUM
REVISTA DE CIENCIA Y TECNOLOGÍA EN LA CULTURA FÍSICA

Translated from the original in spanish

Original Article

Biomechanical analysis of the Mawashi Geri Jodan kick in Karate-Do

Análisis biomecánico de la patada Mawashi Geri Jodan en el Kárate-Do

A análise biomecânica do pontapé de Mawashi Geri Jodan no Karate-Do

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Received: Noviembre 25th, 2019.
Approved: January 21th, 2020.

ABSTRACT

The current expectations of contemporary sport have imposed challenges that necessarily imply, from positions of science, the constant search for new technologies that will allow athletes to raise their sporting performance, from which karate-do has not been exempt. In the present research, a study of the biomechanical characteristics that contribute to the fulfillment of the technical pattern of the Mawashi Geri Jodan kick was carried out, with the objective of proposing the procedure for its analysis, considering the biomechanical indicators that guarantee its technical pattern. For this purpose, a sample of six athletes from the dojos of the Pinar del Río municipality was worked on, as well as a secondary sample of six coaches and eight specialists. Scientific research methods and techniques were used, such as analytical-synthetic, inductive-deductive, document analysis, observation, interview, videography, measurement and expert judgment. To achieve the purpose, a methodology was taken as reference, identifying the biomechanical characteristics that contribute to the result of this technique, which were complemented by the analysis of the deterministic model built. Once the biomechanical characteristics that make possible the successful implementation of this technique were selected, the quantitative analysis of the variables with their correspondence in the incidence of the result of the implementation of the technical movement through video recording was carried out by means of expert criteria. The determined biomechanical

characteristics that appear in the deterministic model constructed for the technique, are feasible for the analysis of the quality of the execution of this kick.

Keywords: biomechanical analysis; Mawashi Geri Jodan technique; analysis of technical preparation in karate.

RESUMEN

Las expectativas actuales del deporte contemporáneo han impuesto retos que necesariamente implican, desde posiciones de ciencia, la búsqueda constante de nuevas tecnologías que permitan elevar el resultado deportivo de los atletas, de lo cual no ha quedado exento el kárate-do. En la presente investigación, se realizó un estudio de las características biomecánicas que tributan al cumplimiento del patrón técnico de la patada Mawashi Geri Jodan, con el objetivo de proponer el procedimiento para su análisis, considerando los indicadores biomecánicos que garantizan su patrón técnico. Para ello, se trabajó con una muestra de seis atletas de los dojos del municipio Pinar del Río, así como una muestra secundaria de seis entrenadores y ocho especialistas. Se emplearon métodos y técnicas científicas de investigación como el analítico-sintético, inductivo-deductivo, análisis de documentos, la observación, la entrevista, la videografía, medición y el criterio de expertos. Para lograr el propósito, se tomó como referencia una metodología, identificando las características biomecánicas que contribuyen al resultado de esta técnica, las que fueron complementadas por el análisis del modelo determinístico construido. Una vez seleccionadas las características biomecánicas que posibilitan la ejecución exitosa de esta técnica, se procedió, mediante el criterio de expertos, al análisis cuantitativo de las variables con su correspondencia, en la incidencia del resultado de la ejecución del movimiento técnico mediante la videograbación. Las características biomecánicas determinadas, que aparecen en el modelo determinístico construido para la técnica, son factibles para el análisis de la calidad de la ejecución de esta patada.

Palabras clave: análisis biomecánico; técnica Mawashi Geri Jodan; análisis de la preparación técnica en el kárate.

RESUMO

As expectativas atuais do desporto contemporâneo impuseram desafios que implicam necessariamente, a partir de posições da ciência, a constante procura de novas tecnologias que permitam aos atletas elevar o seu desempenho desportivo, do qual o karate-do não tem sido isento. Na presente investigação foi realizado um estudo das características biomecânicas que contribuem para o cumprimento do padrão técnico do pontapé Mawashi Geri Jodan, com o objectivo de propor o procedimento para a sua análise, considerando os indicadores biomecânicos que garantem o seu padrão técnico. Para isso, foi trabalhada uma amostra de seis atletas dos dojos do município de Pinar del Río, assim como uma amostra secundária de seis treinadores e oito especialistas. Foram utilizados métodos e técnicas de pesquisa científica, tais como análise analítico-sintética, indutivo-dedutiva, análise documental, observação, entrevista, videografia, medição e julgamento por especialistas. Para alcançar o objetivo, tomou-se como referência uma metodologia, identificando as características biomecânicas que contribuem para o resultado desta técnica, as quais foram complementadas pela análise do modelo determinístico construído. Uma vez selecionadas as características biomecânicas que tornam possível a execução bem-

sucedida desta técnica, a análise quantitativa das variáveis com sua correspondência na incidência do resultado da execução do movimento técnico por meio da gravação em vídeo foi realizada por meio de critérios de especialistas. As determinadas características biomecânicas que aparecem no modelo determinístico construído para a técnica, são viáveis para a análise da qualidade da execução deste chute.

Palavras-chave: análise biomecânica; técnica de Mawashi Geri Jodan; análise da preparação técnica em karatê.

INTRODUCCTION

In sport, it is increasingly difficult to improve a result that is far removed from new technologies and modern training systems. Today, sports professionals have to think that the competitiveness of sport is increasingly based on the efficient application of science and technology.

The observation of the movement that is executed is a permanent task of the professionals of the sport to know if the motor actions have been carried out in correspondence with the pattern of the technique, if they have been carried out in a correct or incorrect way and their causes.

In any sport modality, the athlete executes a certain number of technical movements at high speed, which is why it is very difficult for the coach, no matter how much experience he has and a specialized eye, to determine how the technique has been executed.

The technological advances in computing and communications provide a solution to this problem, as the trainer has videos of the execution of the technique and movement analysis software. These technological advances allow, besides the qualitative analysis of the movement from if a series of criteria for its execution are fulfilled, the analysis from the numerical values that reach the mechanical variables that guarantee the result of the motor action (Acero, J.A. 2004 y Zissu, M. 2012).

Among these advances is the current development of Biomechanics, evidenced by new research procedures and techniques, in which it is possible to recognize the growing trend in combining various scientific disciplines in the analysis of movement. In recent years, progress in measurement techniques, data storage and processing have contributed greatly to the analysis of human movement.

A successful trainer must know the characteristics of the movement under analysis, as well as the factors that contribute to the smooth (and skilful) execution of the movement. A defective technique will prevent the athlete from using his maximum physical capacities (strength, flexibility, resistance, etc.), preventing the improvement of his performance (Soares Leite, W., 2012).

It is essential for sports teachers to know the biomechanical foundations that justify the athlete's movements, especially in high performance, because they work to achieve maximum sports performance in their athletes, which depends on precision in the details. On the other hand, it is also useful for the athlete, since, having a clear knowledge of the details and the causes that can improve or worsen their executions, they manage to improve their technique, accelerating the learning of it, since they are able to establish the relation between the cause and the effect of their

movements, aspects that turn this science into an instrument that reports, as much to the sports teacher as to the athlete (Perdomo, Perdomo and Sánchez, 2018).

In the specific case of combat sports such as taeK-won-do and karate-do, there are recent studies which analyze, from the perspective of Biomechanics, different technical elements of these sports, such as those published by Soto Benalcázar, (2015); Avitia and Reina, (2016), Loachamin *et al.,* (2017); Barreno López, (2017) and Hariri and Sadeghi, (2018).

Karate-do is a combat sport that allows the accumulation of diverse strengths when performing different technical movements, characterized by its speed, fluidity and strength, maintaining concentration as a fundamental basis. This sport discipline is a fighting system, based on impact that reaches its maximum effectiveness in medium distance confrontations; it is generally based on a strong muscular action to develop strength.

Within the technical elements of karate-do, the kick is one of the fundamental techniques and of difficult execution; within them, the Mawashi Geri Jodan is one of the kicks that is most useful in the competitive system (Hariri, S. and Sadeghi, H., 2018), since it is one of the ones that has the maximum score value and it is the first one that is taught because it is the one with the least technical complexity.

If in the trainings the visual appreciation is used as the only indicator to analyze the fulfillment of the pattern of the movement, it will not be possible to determine if the laws of mechanics have been used correctly to achieve the movement that guarantees the model or pattern made. It is precisely this situation that provides us with the background that constitutes the problematic situation that leads us to carry out this research.

In visits made to the dojos of the municipality of Pinar del Río, it has been observed that the coaches perform the analysis of the athletes' technique by the traditional method, direct observation when the athletes execute the movement and in interviews with the coaches, it is appreciated that they do not know the procedure to follow to perform the biomechanical analysis, applying the advanced technology available.

Based on the above, the control of the Mawashi Geri Jodan technique is insufficient, it is only done through direct observation when the athletes execute the movement. With this form of control, in spite of the experience of the trainers, it is impossible to obtain the necessary information about the fulfillment of the pattern of the technical movement, what makes difficult the improvement of the technique and, as consequence, the competitive performance of the same ones.

Therefore, the present research is carried out with the objective of proposing the analysis procedure of the MawashiGeri Jodan technique in the dojos of the municipality of Pinar del Rio, considering the biomechanical indicators that guarantee its technical pattern and thus contributing to the teaching process and improvement of this valuable technique in the competitive result of the athletes.

MATERIALS AND METHODS

In carrying out the research, theoretical and empirical methods and corresponding techniques were used, which are described below.

Throughout the research process, the analytical-synthetic method was present, but with greater emphasis during the evaluation of the information collected, in the determination of regularities and trends of the Mawashi Geri Jodan technique, as well as when the factors that influence this technique were studied and the biomechanical indicators that characterize this kick were determined.

The inductive-deductive method also manifests itself throughout the research; in particular, these logical processes were present when inferring the biomechanical characteristics that influence the outcome of the technique under study and the adoption of the deterministic model.

The document analysis method was used to review all the sources of consultation, materials, texts and articles that supported our research, giving it a theoretical and methodological support.

Direct observation was used during 20 training sessions to 6 green belt athletes from the dojos of the Pinar del Rio municipality, with the purpose of getting to the diagnosis of the problematic situation and in the process of obtaining the video and its analysis.

Indirect measurement was also applied to these six athletes, evaluating the biomechanical characteristics of the execution of the Mawash iGeri jodan kick, particularly the spatial, temporal and space-time kinematics. For the analysis of the movements, the software KINOVEA-version 0.8.27 was used, which is being used in the biomechanical researches for the execution of kinematic studies.

Likewise, an interview was applied to six coaches with more than ten years of experience in this work, who were in charge of carrying out the training process; a guide was used, designed with the purpose of knowing the considerations in relation to the established process to achieve the improvement of the Mawashi Geri Jodan technique in their athletes.

Videography was also used in the six athletes mentioned, a biomechanical technique that made it possible to record the data related to the motor action under study and the subsequent analysis of the results, as well as to obtain the quantitative characterization of the previously selected indicators.

The theoretical evaluation of the proposed procedure was carried out using expert criteria. To this end, a group was formed, made up of eight experts of recognised authority and suitability in the field, all graduates in Physical Culture, with a high competence coefficient in the subject, an adequate academic level related to the profile of the work and with more than ten years linked to the activity.

RESULTS AND DISCUSSION

Once the research methods and techniques had been applied, the information obtained from the revised theory was analyzed. We began by identifying the biomechanical characteristics that contribute to the result of the Mawashi Geri Jodan kick and took as reference the methodology proposed by Ferro and Floria, (2007).

This structure, although it was established for the analysis of the discus throw, is viable for all motor action.

In this methodology, the authors propose the following steps:

1. Collect technical movement relevant information.
2. Set the final target of the movement.
3. Divide the movement into phases.
4. To fix the criteria of biomechanical effectiveness of each phase.
5. Identify the technical aspects used by the trainers to teach the technique and improve it.
6. Identify and define the biomechanical variables that are related to those technical aspects.
7. Point out the assessment criteria.
8. Note down the values provided by the literature for these same biomechanical variables.

The methodological alternative proposed by Ferro and Floría, (2007) consists of eight steps, but for the purposes of this reference, only steps 1, 2, 3, 4 and 6 were selected.

1- Gathering the relevant information on the technical movement.

In this first step, an exhaustive process of synthesis of information from sources was carried out, like the own observation of the execution of the kick by the studied athletes, of meetings maintained with sport technicians to know their restlessness, as well as the procedure that they use for the teaching and improvement of the MawashiGeri Jodan kick and of the bibliographical review on biomechanics and the training of the technique object of study.

2- Set the final objective of the movement.

The second phase consisted of expressing with precision the final objective of the movement. According to Kreighbaum and Barthels, (1996), each of the phases has its own mechanical purpose that facilitates and contributes to the successful accomplishment of the general performance objective.

To determine the mechanical purpose in this phase, it was taken into account that in karate, the competitive result is decided by the accumulated score. Then, the final objective of the studied movement is to score in the upper part of the upper train, in the shortest time possible.

3- Divide the movement into phases.

To divide the movement into phases, the criteria of Donskoi, D. (1988), about the kinematic structure of the movements were used, for which, according to the same author, the external frame is taken, taking into account the form and character of the movement.

Taking into account this criterion, in the different sports disciplines, as well as in Karate, three phases are proposed: initial, main and final, according to the Integral Programme of Preparation of the Karate Athlete (Sánchez, I. *et al.,* 2013).

In the works and authors consulted such as Zissu, M. (2012), Soto, E.A. (2015) and Toro, A. (2018), in relation to offensive actions in Karate and the execution of the Mawas hiGeri Jodan technique, three phases are also described: preparatory phase, integrated by the actions of the guard position and the movements to approach the adversary; active phase, understood from the moment in which the foot that executes, loses the contact with the tatami and achieves the contact with the adversary and the recovery phase or the phase of return to the initial position (of guard).

In this research, the study was directed only to the active phase, considered as the fundamental one in this motor action, delimiting it from the instant in which the trunk begins the movement of rotation in the direction of the movement of the inferior executing member, during the bipodal support, until the inferior executing member achieves the contact with the adversary (Figure 1).

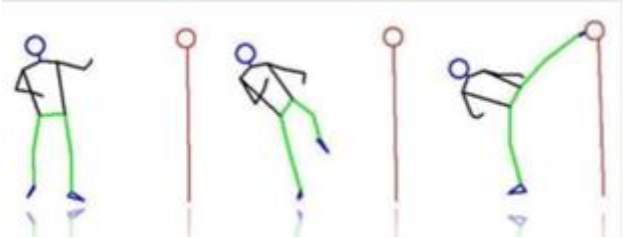

Fig. 1. - Active phase Mawashi Geri Jodan

4- Establish the criteria of biomechanical effectiveness of each phase.

Once the phase to be studied had been defined, the biomechanical effectiveness criteria that must be met in order to achieve the mechanical objective of this phase, specified in the second step of the methodology, were established.

The starting point for this phase is that the objective is to mark the upper part of the upper train in the shortest possible time.

When analyzing the mechanical purpose of this phase, the following were determined as the biomechanical effectiveness criteria that must be met in order to achieve it:

- The stability of the body during unipodal support, adopting a posture that allows the location of the body's center of gravity within the support base and keeping the entire sole of the supporting member seated on the floor.
- Reaching high speed in the lower executing member, but controllable to stop the movement, moments before contact with the adversary

5- Identify and define the biomechanical variables that are related to the technical aspects.

Analyzing the results of the whole process followed by the observation and discussion of the technical execution with the coaches of the athletes studied, it was considered that there are two essential mechanical factors in the execution of this motor action: the stability of the athlete's body and the speed of the lower executing member and, from them, the following spatial, temporal and space-time characteristics were identified that contribute to the achievement of the technical aspects in the Mawashi Geri Jodan kick:

Special characteristics:

Angular positions of the body segments: Angle of flexion and extension of the knee and of inclination of the trunk (Figure 2).

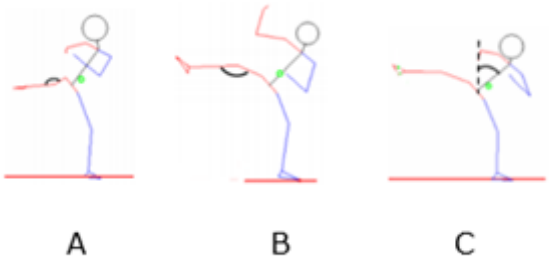

Fig. 2. - Angular positions

Knee flexion angle (A). In order to achieve the maximum speed of the lower executing member, the knee should be bent as far as possible and the heel should be attracted as much as possible to the buttocks, thus increasing the space for acceleration and contributing to the increase in speed, the criterion by which this feature was selected.

Knee extension angle (B). To take advantage of the acceleration space and contribute to high speed values, the knee should be fully extended to an angle of 180 º.

Trunk angle (C). The trunk should be inclined in the opposite direction of movement, in order to keep the body's center of gravity above the support base to maintain the stability of the body, recommended as the ideal angle of inclination of the trunk of 45 º.

Location of the body's center of gravity (CGC) and position of the heel of the lower support member (Figure 3).

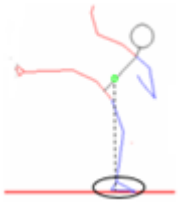

Fig. 3 - Location of the body's center of gravity

Location of the body's center of gravity (CGC). This characteristic was selected because the fundamental factor determining the stability of bodies is the location of the CGC within the support base.

Position of the heel of the lower support member. It is important to seat the entire sole of the foot of the lower support member on the tatami so as not to minimize the basic support area, in order not to make the movement more unstable than it is with this unipodal support.

Temporary characteristics

Time of the active phase; of the maximum flexion subphase and the knee extension subphase. These characteristics are taken with the objective of evaluating the duration of the subphases of flexion and extension of the knee. To contribute to high speed results, the extension subphase should have a shorter duration, which should be less than and equal to 0.15 seconds to take advantage of the accumulated elastic energy.

Temporary-space characteristics:

Behavior of speed, acceleration and their components in the knee and ankle (Figure 4).

Fig. 4. - Speed and acceleration behaviour

Linear speed behavior at the knee and ankle (A). To analyze the occurrence of the velocity resultant and its components during the entire trajectory.

Behavior of the linear acceleration of the knee and ankle (B). To analyze the manifestation of the resultant of the acceleration and its components during the whole trajectory.

On the basis of the mechanical purpose of the determined active phase and of the effectiveness indicators, both qualitative and quantitative identified, the deterministic model for the active phase of the Mawashi Geri Jodan technique was constructed, since it constitutes a structured pattern, in a schematic and logical way that allows visualizing, in a clear way, the interrelation that exists between the result (objective) that is pursued and the mechanical factors that intervene so that this one is achieved, which allows, finally, the complementation of the obtained results.

This model created by Hay and Reid, (1988), is based on the cause-effect relationship, starting from the performance parameters (result), of a given sports specialty, expressed by means of a block diagram. It is a subordination of biomechanical characteristics in sequence, where the lower ones explain the higher ones.

The constructed model that visualizes the interrelationship between the result (objective) that is pursued and the mechanical factors that intervene so that this one is achieved, referred to the active phase of the MawashiGeri Jodan technique, is shown next (Figure 5).

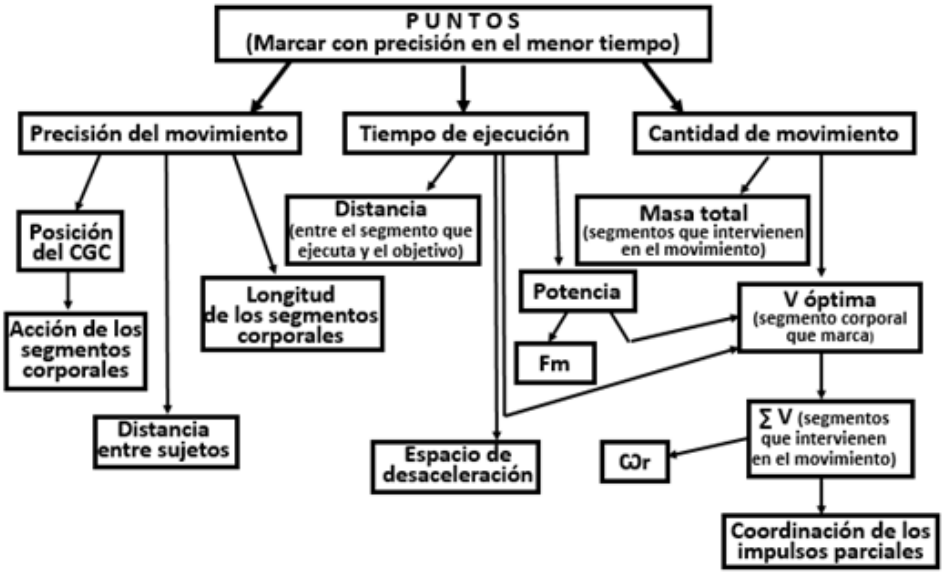

Fig. 5. - Deterministic Model for the Mawashi Geri Jodan

In the process of building the model, another aspect to be highlighted for the definition of the biomechanical characteristics was analyzed; the biomechanical analysis of the execution of the movement on the basis of the biomechanical principles defined by Hochmuth, G. (1973), which become evident during the execution. Identifying the Principle of coordination of partial impulses.

Compliance with this principle guarantees high values of speed. The impulses must be coordinated from the movements of the hip, thigh, leg and foot, since the resulting speed is given by the sum of the speeds developed by each body segment involved in the movement.

Another principle of Hochmuth, G., (1973) that contributes to the result of this technique is the Principle of action and reaction. By turning the trunk in the opposite direction to the turn of the lower limb that executes the action of kicking, as a reaction to that movement, turns the hip and lower limb as an extension of it, in the opposite direction, facilitating the technical movement and increasing the speed of the lower limb executor.

The biomechanical characteristics determined as influencing the outcome of the execution of the Mawashi Geri Jodan were subjected to expert analysis. By examining the results obtained with this method, it was easy to see that the theoretical design applied for its selection is very appropriate according to the category given to the different parameters evaluated.

When calculating the Kendall concordance coefficient (W) to measure the degree of agreement of the experts in the answers to the questions made in this respect, a value of 0.81 ($W = 0.81$) is obtained, which expresses a high degree of agreement among the experts, which shows that the characteristics selected theoretically influence with a high degree the quality of the execution of the kick under study.

In order to verify in practice the influence of these characteristics in the execution of the Mawashi Geri Jodan, we proceeded to the qualitative analysis of the execution of this technique by the athletes under study; it was verified the influence that had the

behavior of the values obtained from the different biomechanical characteristics selected in the successful execution of this technique. Some examples are shown below (Figure 6).

Special characteristics:

Angular positions of the body segments:

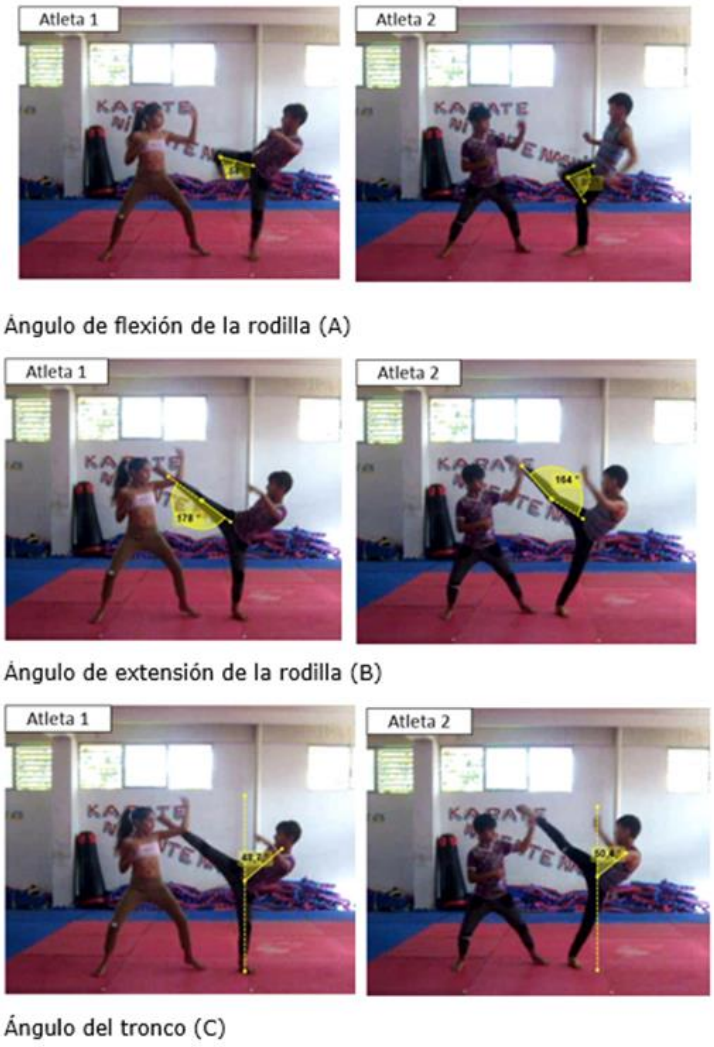

Fig. 6. - Measurement of angular positions

Knee flexion angle (A): when calculating the knee flexion angle, the value obtained for athlete 1 was 54º and for athlete 2 was 80º. Valuing qualitatively the technique executed by the athletes, it was remarkable the quality of the first one in relation to the second one, so it was inferred that this biomechanical characteristic influences the success of this technique.

Trunk angle: when analyzing the results obtained with respect to the angle of inclination of the trunk in the athlete 1, it was 48.7 ºy the athlete 2 was 50.4º As you can see, the athlete 1 is closer to the ideal angle of 45º, performing a better execution of the movement with respect to the second one, so it was deduced that this biomechanical characteristic affects the result of this technique.

Location of the body's center of gravity (CGC) and position of the heel of the lower support member (Figure 7).

Fig. 7. - Representation of the body's center of gravity

Location of the body's center of gravity (CGC): in relation to the results obtained, it can be appreciated that in the athlete 1, the vertical of the center of gravity falls inside the base of sustentation, not being this way in the athlete 2, where his center of gravity falls out of the base of sustentation, having better possibilities of scoring points the first athlete than the second one, for what it was concluded that this biomechanical characteristic affects the result of the technique.

Position of the heel of the lower support member: When evaluating the position of the heel of the lower support member, it was observed that the athlete 1 sits the entire sole of the foot on the tatami, while the athlete 2 performs a slight elevation of the heel. Analyzing the movement executed by both athletes, it was observed that the first athlete has better technical execution than the second one, so this biomechanical characteristic influences the result of this technique.

Temporary characteristics:

Time of the active phase; of the maximum flexion subphase and the knee extension subphase (Figure 8).

Fig. 8.- Time of the active phase

Time of the active phase: when calculating the time of the active phase, the value obtained in the athlete 1 was 0.37 seconds and in the athlete 2, it was 0.40 seconds. Valuing the differences in the times of the subphase of the knee extension, it is demonstrated that the first athlete executes faster than the second, so it was inferred that this biomechanical characteristic is very important in the achievement of this movement.

Temporary-space characteristics:

Behavior of speed, acceleration and their components in the knee and ankle (Figure 9).

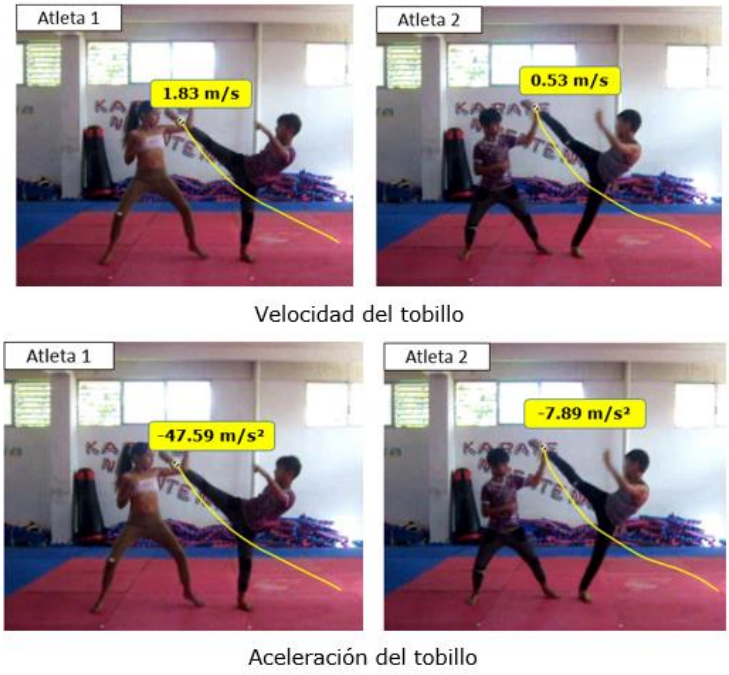

Fig. 9. - Calculation of speed and acceleration

Ankle linear speed behavior: when calculating the ankle speed behavior in the active phase, it can be seen that athlete 1 recorded a speed of 1.83 m/s and that in athlete 2 it was 0.53 m/s. Analyzing the technique executed by the athletes, it was observed that the first one performs the movement better than the second one, so it was inferred that this biomechanical characteristic influences the result of this technique.

In the same way, the results of the speed components in the athlete 1 are better than in the athlete 2, since he is able to guarantee high values of speed, compromising in the movement each body segment that intervenes in the kick. Complying with the principle of coordination of partial impulses.

Behavior of the linear acceleration of the ankle: when calculating the acceleration, the value obtained in the athlete 1 was of -47.59m/s² and in the athlete 2, it was of -7.89 m/s ². When analyzing the execution of the movement, it is observed that the athlete 1 performs the technique closer to the scoring area than the athlete 2, so it was inferred that this biomechanical characteristic influences the result of this movement.

The results obtained, through the analysis of the movement and the criterion expressed by the experts, show that the selected biomechanical characteristics influence with a high degree the quality of the execution of the kick under study and it is thus demonstrated that the biomechanical characteristics influence the result of the motor action. There is an interrelationship between the behavior of the biomechanical characteristics and the quality of the execution of the technique.

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Conflict of interests:

The authors declare not to have any interest conflicts.

Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents.

ISSN: 1996–2452 RNPS: 2148
Revista PODIUM, *January-April 2020; 15(1): 111-126*